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Method for high-Speed Manchester encoded optical signal generation

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Abstract: A method for high-speed Manchester encoded optical signal generation is proposed and demonstrated with a specially configured electro-optical modulator. A 10 Gb/s Manchester encoded optical signal was generated, and its bit-error-ratio (BER) performance was evaluated.

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1. Introduction

Manchester coding, also known as bi-phase coding, is a 1B/2B coding scheme. Although it requires double bandwidth compared to non-return-zero (NRZ) coding, Manchester coding has been shown to present several advantages, such as enabling a simple clock extraction operation. Furthermore, its differential detection scheme exhibits a high-level intensity fluctuation tolerance [1], verifying itself as a promising coding for high-speed burst mode transmission links [2]. In addition, Manchester coding greatly reduces low frequency components through spectrum shaping, hence having several applications in improving the modulation performance of network nodes [3] [4].

Electrical exclusive OR (XOR) gates are customarily used for implementing Manchester coding. Although the potential of electrical XOR operation has been reported at bit rates as high as 40 Gb/s [5], a Manchester encoded optical transmitter operating above 10 Gb/s is still difficult to implement due to the scarcity of high-speed electrical logic gates.

In this paper, we propose a novel method to implement high speed Manchester coding with an electro-optical Mach-Zehnder modulator (MZM). Unlike previous methods, it does not require any electrical logic gate. A 10 Gb/s Manchester encoded optical signal is generated using this new technique, and its BER performance is evaluated.

2. Proposed Method

A Manchester code can be obtained through an XOR operation between an original NRZ signal and a clock signal. Consequently, there is always a transition, either rise or fall, at the middle of each bit period, which represents the "1" or "0" symbol respectively. Our proposed method is mainly based on a dual-drive Mach-Zehnder modulator (MZM). By driving the MZM with both a NRZ data and a clock signal and biasing it to perform the XOR operation directly in the optical domain, a Manchester-encoded optical signal can be generated while no electrical XOR gates are needed.

Table 1 XOR operation of an electro-optical Mach-Zehnder modulator

V_{a1}	V_{a2}	$ V_{a1}-V_{a2} $	$I(V_b=0)$	$I(V_b=V_\pi)$
High	High	Low	High	Low
High	Low	High	Low	High
Low	High	High	Low	High
Low	Low	Low	High	Low

We show that, when the modulator is biased to induce zero or π phase shift between the arms, the modulator will perform an XOR operation between the input signals. The output intensity of the modulator is given by

$$I = I_0 \cos^2 \left[\frac{1}{2} \cdot \frac{\pi}{V_\pi} \cdot (V_b + V_{a1} - V_{a2}) \right] \quad (1)$$

Where I_0 denotes the intensity of the CW light, V_π denotes the half-wave voltage of the modulator, V_b denotes the bias voltage difference between the two arms, and V_{a1} and V_{a2} denote the modulation voltages in the two arms. With the reasonable assumption that $|V_{a1} - V_{a2}| \leq V_\pi$, Table 1 is derived according to equation (1), which verifies the XOR logic relation between the electric input signals and the optical output signal. In this sense, the Mach-Zehnder modulator acts as an electro-optical XOR gate and can therefore be used to implement Manchester coding.

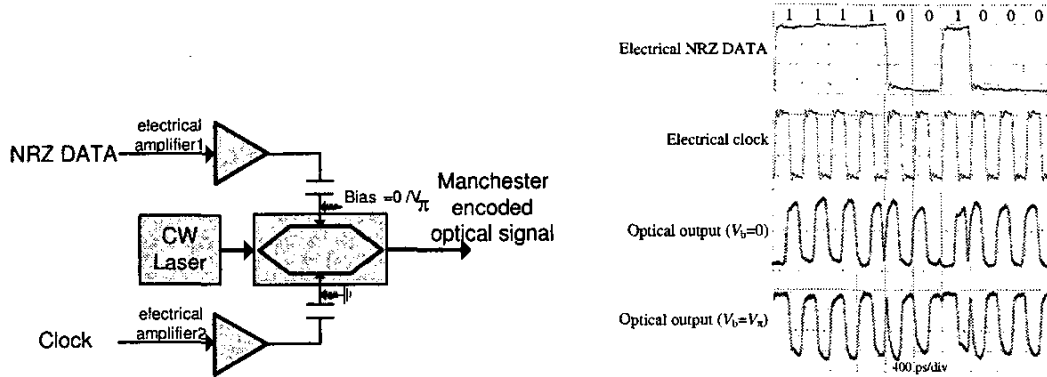


Fig. 1 The proposed Manchester coding method

As shown in Fig. 1, the MZM is configured to perform the logic operation between a NRZ data and a clock signal. As indicated by the measured output waveform shown in Fig. 1, the symbols are finally transformed into transition edges at the middle of bit periods, thus achieving Manchester coding.

3. Experimental Setup and Results

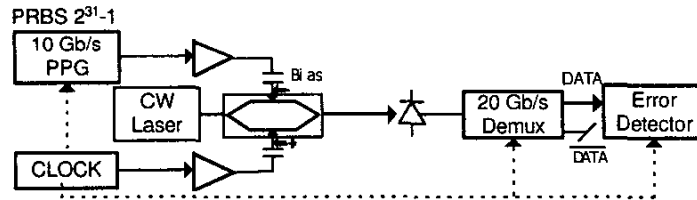


Fig. 2 Experimental setup of an optical FSK labeled signal transmission link

The experimental setup is shown in Fig. 3. A 10 GHz clock signal and a 10 Gb/s NRZ pseudorandom bit sequence (PRBS) with $2^{31}-1$ pattern length drive a MZM with a bandwidth of 15 GHz. The peak-to-peak values of both input signals are amplified up to 7 volts, which is nearly equal to the half-wave voltage V_π . The generated Manchester coded signal is then received by an optical receiver with a bandwidth of 20 GHz. By using a 20 Gb/s 1:2 electrical demultiplexer, the signal can be decoded and its bit-error-ratio is measured by a 10 Gb/s error detector.

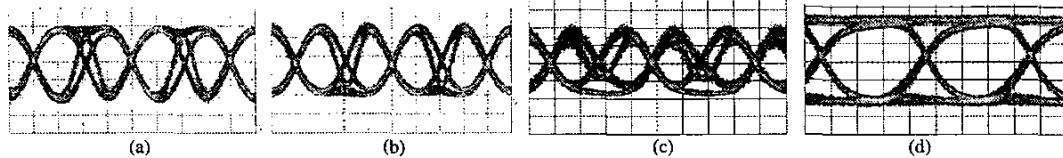


Fig. 3 Eye-diagrams of 10 Gb/s Manchester encoded optical signal when (a) the modulator is biased at minimum transmission; (b) the modulator is biased at maximum transmission; (c) received and equalized by electrical filter; (d) decoded by a 20 Gb/s electrical demultiplexer

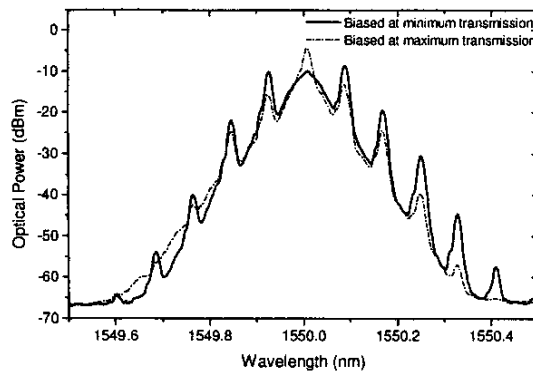


Fig. 4 Optical spectra of Manchester encoded optical signals (resolution bandwidth= 0.01 nm).

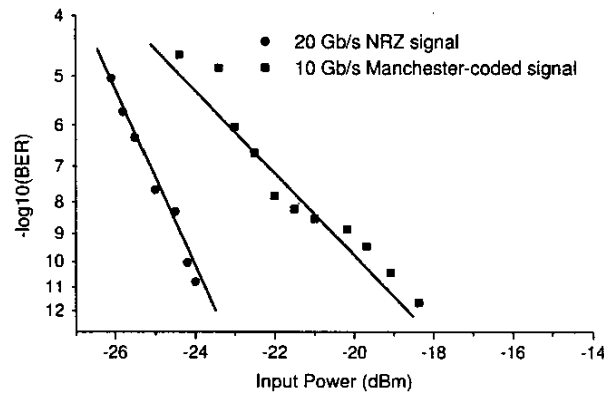


Fig. 5 Measured BER performance

As indicated by Fig. 3(a)-(b), the generated Manchester eye-diagram exhibits a good eye-opening while having a high extinction-ratio of 13 dB when the modulator is biased at minimum transmission. The eye-diagrams also show amplitude dips corresponding to some phase changes swinging across zero or π . As these dips are only located at the boundaries of the bit intervals and can be mitigated by electrical filtering, as indicated by Fig. 3(c), they should only have a minor effect on system performance. Since such a configuration also provides a DC balanced modulation of both optical amplitude and phase, the carrier component in the spectrum is suppressed, as can be seen in Fig. 4. The generated signal has an error-free performance and the receiver sensitivity at $\text{BER}=10^{-9}$ is about -20.5 dBm, as shown in Fig. 5. Compared with a 20 Gb/s NRZ signal, the power penalty induced by the Manchester coding is about 3 dB. However, the receiver sensitivity could be further improved with a differential detection scheme.

4. Conclusions

In conclusion, we have proposed and demonstrated a novel method to implement high-speed Manchester coding. The generated 10 Gb/s Manchester encoded signal shows error free performance.

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